THE INHIBITING FACTORS THAT PRINCIPAL INVESTIGATORS EXPERIENCE IN LEADING PUBLICLY FUNDED RESEARCH PROJECTS

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ABSTRACT

Securing public funding to conduct research and leading it by being a principal investigator (PI) is seen as significant career development step. Such a role brings professional prestige but also new responsibilities beyond research leadership to research management. If public funding brings financial and infrastructure support, little is understood about the inhibiting factors that publicly funded PIs face given the research autonomy offered by publicly funded research. Our study finds that there are three key PI inhibiting factors 1) political and environmental, 2) institutional and 3) project based. Traditional knowledge, skills and technical know-how of publicly funded PIs are insufficient to deal with the increasing managerial demands and expectations i.e. growing external bureaucracy of public funding agencies. Public funding is no longer the 'freest form of support' as suggested by Hackett (1990) and the inhibiting factors experienced by publicly funded PIs limits their research autonomy. We also argue that PIs have little influence in overcoming these inhibiting factors despite their central role in conducting publicly funded research.

Key Words: Publicly Funded Research; Principal Investigators; Inhibiting Factors; Research Leadership; Research Management; Research Autonomy.

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1. INTRODUCTION

Public funding of research has had a significant influence and impact on research in universities and publicly funded research laboratories. Success in securing public funding provides enhanced legitimacy to recipient institutions, research groups and academics and comes with additional transparency requirements that are not required for other sources of funding. Public funding is considered to provide researchers with research autonomy to support frontier and applied research projects that are relevant to sciences, society and may have commercial applications. Key actors in delivering publicly funded projects are principal investigators (PIs). However, even if the numbers of publicly funded PIs have grown significantly in the last decade and academic communities see the position as a prestigious career step, we know little about the experiences of publicly funded PIs who contribute to the advancement of new knowledge. With increased mandates from government to see that public research achieves economic as well as scientific impact through technology transfer activities, the research leader, in this case the publicly funded PI, is therefore a critical player in determining technology transfer success (Siegel *et al.*, 2003 ; Thursby *et al.*, 2001; Thursby *et al., 2011*.).

Universities and public research laboratories have expanded their core missions to research commercialisaiton and technology transfer(Libaers *et al.*, 2006; Owen-Smith *et al.*, 2003; Palmberg, 2008). This has resulted in such organisations dealing with a core tension of promoting a culture of risk taking and balancing this against an externally imposed bureaucrary that comes with securing public funding. PIs are at the heart of experiencing and dealing with this tension. Therefore, our core research question is focused on examining the inhibiting factors that publicly funded PI experience.

We begin the paper by outlining the characteristics of publicly funded research, the benefits of publicly funded reserch and the organisational context of publicly funded research. We then focus our attention on the status and tasks of publicly funded PIs and the methodology used to conduct this study. In our finding section we present the three key inhibiting factors experienced by publicly funding PIs namely *political and environmental*, *institutional and project based* and we also discuss the level of interest and control that the PIs have over these inhibiting factors.In our conclusion section we argue based on our findings that the prioritisation of discovery must be protected, that publicly funded PIs are not sufficiently supported by their own insitutions or funding agencies in dealing with research bureaucracies and they are not adequately prepared for research management which is beyond their core craft skills.

2. CONCEPTUAL CONSIDERATIONS

2.1. Characteristics of Publicly Funded Research

Characteristics of publicly funded research vary across nations and stakeholders within national innovation systems as publicly funded research schemes have different priorities designed to support national scientific, economic and social priorities (Mangematin, 2004). By increasing public funds for research, particularly basic research, government can be seen to expand the pool of economically useful information. A summary of the characteristics of public research is presented in Table 1.

- Insert Table 1 about here

Much research has focused on the empirical benefits of public research. In addition to the increased stock of useful, benefits from public research are considered to accrue at different levels – to the the public, to the research institution and to the individual scientists. Table 2 summarises these benefits.

- Insert Table 2 about here -

Principle investigators are running publicly funded research activities within universities and public research laboratories which are involved in the third mission or ‘entrepreneurial’ activities as part of their core activities (Klofstenet *et al.*, 2000), bridging universities and industries and positioning universities at the centre of the knowledge production system through collaborative mechanisms (Clark, 2011).PIs are not only leading research and shaping research avenues. They are also managing public funding within universities which have adopted “the rules and formal rationality of government bureaucracies” (Hackett, 1990). The publicily funded PI is impacted by these requirements and the associated norms within their own institutional setting.

For university leaders who must now govern over an expanded mission focus and a public funding resource dependency this raises some fundamental tensions as to how : “to create a cultural environment that promotes risk taking, self-confidence, optimism, and ambition.” (Glassman *et al.*, 2003). These increased expectations as Hackett (1990) describes: “are not intrinscially unhealthy principles for conducting research, but such departures

from past practice may entail an uncomfortable period of accomodation for many. … these new practices are changing the working conditions for principal investigators and their teams in ways that might reduce the educational benefit of the experience." Other sources of research funding may not require the same levels of accountability and transparency.

The tensions contained within public knowledge production systems have resulted in changes to the academic work environmental in universities in the USA, Europe and Australasia (Preston, 2002). University administrators have become focused on putting in place managerial structures, systems and approaches that enable institutions to monitor and assess performance. This has also lead to increasing the visibility and importance of research, research management and administration (Shelly, 2010). Such changes and the addition of new organisational roles such as research managers has implications for publicly funded PIs and as such potentially creates inhibitors for them in delivering publicly funded research projects in what Duberley (Dany *et al.*, 2011; Duberley *et al.*, 2006) describes as more "commercial and managerial environments." Publicly funded PI are caught in middle of this change.

2.2. Status and Tasks of Publicly Funded Principal Investigators

The expansion of university missions combined with more commercial and managerial environments has changed the academic profession. This has meant that academics have to become a member of an even greater array of groups while also belonging to a profession, institution and a national system of innovation and education as Clarke (1987)notes: "Academics are caught up in various matrices, with multiple memberships that shape their work, call upon their loyalties and apportion their authority."

For scholars, taking on the role as PI represents an important landmark in their career. Peers, the funding agency, their institution and external stakeholders see becoming a publicly funded PI as prestigious. For example, an academic that is a recipient of a National Science Foundation grant carries what Rosser and Chameau (2006)describe as 'considerable prestige'. It also places additional demands on the PIs institution.

As PI, the lead researcher will be expected to moderate their role identity from that of scientific researcher to incorporate other duties involved in being PI (Jain *et al.*, 2009). The key tasks of publicly funded PIs include leading a research programme, overseeing the day to day management of the project, supervising and sometimes mentoring staff conduct, signing off on the project's budgets and financial management, ensuring all deliverables and deadlines are met, and submitting technical documentation and progress reports. PIs are also expected to take on more significant leadership and managerial roles, whereby they must design and schedule the research project, coordinate and direct a research team, liaise with stakeholders and act as a primary contact point with the funding agency, and flag and respond to institutional or project issues. Publicly funded PIs operate within the dual sets of control mechanisms and bureaucracies prescribed by their own institution and that of the public funding agency : competition for research funding intensified : **"**tighter budgets with small amounts of discretionary support, shorter grant award periods, and higher expectations for the number of publications based on a project's work" (Hackett, 1990). Coupled with the changed the nature of the government society contract Guston and Keniston (1994)increased involvement of marginal scientists (e.g. contract researchers), constrained research topics driven by national strategies (Hessels and van Lente, 2008), and increased levels of faculty commercial engagement (Roach and Sauermann, 2010), new practices and arrangements for publicly funded research are changing the working conditions for principal investigators (Hackett, 1990). While some of these changes may be supportive of their scientific programme objectives, others clearly have potential to inhibit their experience in the delivery of publicly funded research projects. This paper seeks to generate a deeper understanding of the inhibiting factors experienced by publicly funded PIs.

3. METHODOLOGY

This research examines the inhibiting factors that publicly funded PIs experience. The exploratory nature of this research was particularly suited to an interpretative case study research design (Eisenhardt, 1989; Siggelkow, 2007; Yin, 2009). Using such a qualitative approach is consistent with previous research studies that have examined challenges associated with boundary spanning activities (Adler *et al.*, 2009 ; Melkersand Xiao, 2012). Multiple-case studies were used to obtain more robust findings, because, compared to a single case study research design, the emerging theory is better grounded, more accurate and theoretically transferable (Eisenhardtand Grabner, 2007; Yin, 2009). The subjects of analysis are publicly funded PIs who conceived of and/or coordinated their respective projects. These projects are classified as individual case studies and in all there are thirty.

3.1 Data collection and analysis

There were two key phases to the data collection process. The first phase involved compiling a dataset of publicly funded research projects in Ireland's science, engineering and technology sector over the last five years. This phase also involved identifying appropriate projects or cases of study within this sample for closer

examination. Consistent with the concept of theoretical sampling, we looked for projects in which the challenges of mode two knowledge production would be most clearly manifested. Our primary selection criteria ensured that only multi-annual and collaborative (preferably with industry) research projects with a funding value over €250,000 were considered. After narrowing the sample somewhat, we then worked towards developing a final sample of thirty projects with PI who were cross -disciplined, -gendered, -aged, and at different levels in their career. Table 3 presents an overview of the PIs and respective projects that were researched.

- Insert Table 3 about here –

The second phase of data collection included an analysis of documentation collected before, during and after the interview relevant to both the project and the CV of the Principal Investigator(Cañibano *et al.*, 2008; Dietz *et al.*, 2005). Thirty semi-structured interviews (approximately 90 minutes each), amounting to just over 400 pages in transcripts, were deemed an appropriate amount and indeed repetition in the final few PI interviews suggested a saturation point had been reached.

The interview guide explored the PI' observations and behaviour with respect to inhibiting factors. They are asked to list and rank inhibiting factors. All interviews were transcribed and sent back to interviewees for clarification and confirmation. These were then combined with the relevant PI and project documentation in separate project case studies.

The analysis followed the process described in Miles and Huberman(1994) where analysis consists of three concurrent flows of activity: data reduction with the first order analysis when we listed the themes, the second order analysis when we analyse mechanisms by which inhibiting factors play a role, and conclusion drawing/verification. The analysis was centred on the Principal Investigator's inhibitors, their intents, and project, institution and environment characteristics that were seen as constraints or enablers during the project delivery.

This research is not without its limitations. The data collection was in Ireland and it would be beneficial to extend the study internationally as the Irish research system has undergone a significant period of growth over the last decade. However, it would be beneficial to see if other discipline based publicly funded PIs experience the similar inhibiting factors. A similar study of inhibiting factors of other sources of funding would also be worth undertaking. It would also be worth conducting a similar study of inhibiting factors in a well established and resourced publicly funding dependent research system to ascertain the inhibiting factors faced by publicly funded PIs.

4. RESULTS

From our data analysis, Table 4 outlines the three categories of inhibitors that publicly funded PIs experience - political and environmental, institutional and project based. The table identifies the core tension exacerbating each inhibiting factor and the level of interest and control the publicly funded PI has over these factors. We identifed the core tensions around each inhibiting factor from the data we analysed.

- Insert Table 4 about here -

4.1 Political and Environmental Factors

An inhibiting factor experienced by all public funded PIs in our study related to *technology transfer policy*, particularly in relation to *project direction and focus*, *stakeholder demands* and *IP valuation*.

Tensions technology transfer/scientific production: Maintaining project direction and focus as per the research contract and funding agency expectations was identified significant inhibiting factor experienced by all publicly funded PIs in our study. The predominant direction and focus of publicly funded PIs was on conducting research, developing new knowledge and discoveries while fundeing agency expectations was on technology transfer. A senior researcher best explains this inhibitor as: "there is competition between getting international recognition and getting IP because once you publish something you are limited. Knowing how to divide that and to sustain both is crucial and can be challenging. If you go too far down the IP route you don't get the acknowledgement and it doesn't feed through to grants and things like that. And vice versa, if you go too far into publishing etc. you can lose IP, so that is a big challenge." Focus on research and academic outputs or purse technology transfer mechanisms.

Dealing with *competing stakeholder interests,* particularly industry was an inhibiting factor for all the publicly funded PIs in our study. This meant that PIs found themselves balancing the competing expectations from industry partners and funding agencies as the research project rolled out. This best summed up by professor who noted: "Commercialisation would have been more on the agendas of the two industry partners we had." For a publicly funded PI the key tension arises in how to prioritise these competing demands during the course of research project. Five of the study participants are responding to this inhibitor by accounting for stakeholder

expectations in the selection of collaborators. Others are proactively thinking about the technology transfer for publicly funded projects as a research unit leader notes: "the goal that the group here and I have is that we try to do research than can be commercialised."

Another notable technology transfer inhibiting factor that publicly funded PIs experience is *IPvaluation* by TTOs. Excessive valuation of IP and a conservative managerial approach by the TTO can inhibit the exploitation of technology transfer opportunities, as affirmed by a senior professor: "I always think of the universities as wanting to be the gatekeeper, they are almost afraid of letting anything out no matter how good the deal is because maybe it will be even better in the future. In some ways I can understand that positon but it can be somewhat infuriating." This creates a tension for publicly funded PIs when they are attempting to exploit their research for commercial ends.

Poor support reliability of publicly funded by various national and international funding agencies was another significant external inhibiting factor for over seventy percent of our publicly funded PIs. The poor support reliability was identified in the form of short notices given for funding calls, inappropriate timing of funding calls in the academic calendar, and delays in releasing contracts and payments for projects. These issues create a tension for the publicly funded PI about balancing workload and competing in further public funding research calls. It was noted by one PI that some of these issues were avoidable and that the PI's research programme planning could be supported: "as early as they know that they are going to have a call in a certain area they should let us know so that we can do some degree of planning. An extreme case of funding agency failure experienced by the same PI found that despite being successful in the funding competition, that the agency did not have sufficient funding in their budget to support the research.

We found that claritity relating to the *strategy and the transparency of public fund agency* is an inhibiting factor for twenty publicly PIs our study. The issues of the strategic focus, research remit and purpose of publicly funded agencies were considered to be constantly evolving, as were the alignment of national strategies for education, enterprise and research. All publicly funded PIs in our study viewed publicly funded agencies as vital to funding basic and applied research. However, PIs reported that there was a clear need for funding agencies to communicate directly with PIs and associated academic communities their long term research vision in developing activities under their remit.

The final *political and environmental* inhibiting factor that the we found in our study was the variation of engagement and interest by funding agencies with the PIs that they fund. PIs in our study experienced a variation of formal engagements with funding agencies which ranged from regular paper based submissions of six monthly progress reports through to site visits. The majority of respondents in our study (twenty two) expressed frustation at the level of engagement and interest that funding agencies had with them as PIs and in their funded project. The PIs outlined their frustration with what they perceived as a lack of familiarity, and in some cases a lack of interest and knowedge, with the funded research from the funding agencies and their project officers. "Many of the people who administer these projects have never done research, certainly not research at the PI level. They are administrating something about which they don't know a lot about. Many of them in my view are not research literate."(Senior PI). This can put a significant strain on the relationship between the PI, their institution, and the funding agency and industry partners in collaborative project. Some respondents in our study suggested that a "more hands on involvement and more meanginful site visits" would be beneficial to the project particularly with respect to the scientific elements.

4.2 Institutional Inhibitors

We found three significant institutional inhibiting factors that publicly funded PIs experienced – *technology transfer support*, *tailored support for the PI role* and *human capital support*. It should be noted that all the organizations of the PIs in our study had centralized administration services such as finance, human resources and technology transfer.

With increasing emphasis by national governments and associated public funding agencies on technology transfer, it is not surprising that PIs experienced inhibiting factors as to the level of dedicated *technology transfer support* available to them :(1) TTOs seems to be "strong on legal arrangements" as in IP protection but "not so much [strong] on pushing patents out."– socializing and marketing with potential buyers of technology. (2) The expectation among PIs is that TTOs should have the experience and expertise to push technology towards the market once it has been protected. However, the majority of PIs found that it is lacking. (3) Finally, legal and administrative works in TTOs with a predominate commercialization orientation: "the element that I always felt was missing in relation to technology transfer was the kind of savy agent who comes from a technical background, who understands research and research labs, and has a very broad knowledge right across the bio sciences, the health sciences, the physical sciences etc. So they are are able to sit down and connect with you as the PI. They are out there looking, that bit is missing, the actual scanning of the market. ... You have technology transfer offices which are very good in terms of the adminstration, legal work and paper work, and in the middle you have the guy who really could have the killer process for a very large company and he does not know it". In essence, "there is a lot of IP on their books and there is no sales man" explained a research leader.

Another significant institutional inhitibing factor is the lack of or *inadequate support for the pubicly funded PI role*. We found that PIs where frustrated by the organisational constraints of their institutions and the experience of the support they received was not "helpful" and was "compliance" based. This compliance was aligned to the public funding agency requirements., while publicly funded Pis in our study outlined the for need some 'flexibility' and 'proactive' support in delivering on their research objectives and the project as a whole. As one professor described it: "There is a problem with institutional support in general, they seem to tell you what is possible and what you can or cannot do but that is not very helpful." Another senior researcher reaffirmed this: "you are part of the university and you are not the opposition yet you nearly have to remind the people in research accounts that we are all the one team." Four PIs even went so far as to question whether the university wants them to succeed or not. This is a source of tension for publicly funded PIs as they are encouraged by their institution to compete for public research funding. However when they secure public grants, there is inadequate institutional support available. As senior researcher explained: "It seems like you are encouraged to get in funding and then they do everything to stop you progressing with it. If you are talking to someone down in headquarters they will often have no concept of what you are doing or why you are doing it, you are just another number." It seems that inadequate PI institutional support is a systemic issue to do with the culture of "mentoring" and "nurturing". For some PIs the need to create a "nurturing" institutional environment is critical as one respondent put it: "One thing that support structures miss is personalisation, someone sitting on your shoulder giving you advice and guiding you and actually tormenting you as well as mentoring because you sometines need that sort of engagement to do it properly."

The final institutional inhibiting factor that we found of signifiance in our study were to do with *human capital factors* – recruitment of researchers and career paths for researchers. The recruitment of research officers was seen as a "crucial task for the PI" and one that required significant attention and management. Some PIs found this process "cumbersome" with the time between advertising and filling the post often far too long in the context of the project timelines.

Given the reliance on marginal researchers in publicly funded projects, a lack of defined career paths for researchers was seen as a human capital inhibiting factor as PIs experienced high turnover of researchers, and the subsequent loss of tacit knowledge and expertise. This has an undermining on the sustainability and impact of the research effort, particularly where research programmes are built on a series of publicly funded projects. Therefore, a fundamental challenge that exists for the PIs is how best to retain talented researchers, particularly during the critical later stages of projects as contract researchers seek out secure employment. For over half of our study participants this means constantly seeking further public funding to sustain their research teams. As one PI commented: "I struggle with how I can create employments for my team, and not have them constantly looking over their shoulder." The other tension revolves around professional and scientific development. The lack of a career path means higher levels of mobility, a loss of talent and "continuity" for the project. High researcher turnover also means that PIs constantly see their role revert to being "more like a trainer than a scientist". This has implications for career management and professional development for publicly funded PIs that have to manage mobile and short term researchers, while ensuring project continuity for publicly funded projects.

4.3 Project Inhibitors

We found several project level inhibitors that impact on publicly funded PIs and their projects, the most signficant among all PIs in our study being *adminstration*, *lack dedicated professional development support for publicly funded PI role* and the *power of industry partners*.

The most significant project level inhibitor that we found among all the PIs in our study was *administration*. The totality of the administration that is required in being a publicly funded PI is best sumed up by research centre director as: "all of the responsibilty from the initiating the idea right through to winning the funding, putting the infrastructure in place, writing all the reports, managing the budgets and everything that happens in between – it is all down to the PI." Similarly another professor reflected that: "I probably spend most of my time fixing problems as they arise, so this can be down to personnel issues or issues in relation to the technical research, the project's direction, or even the expectations of the different partners, or hiring people. So to be honest I don't spend time writing code or research papers or anything like that, it will be more of a management role." Other publicly funded PIs noted that they spend their time "fixing problems", "writing reports", "collating information" or what one PI described it as being a "glorified secetary." All respondents in our study irrespective of insitutional context explained that their time is increasing consumed in the adminstration rather the research. One professor quantified this as "I would say 40 per cent of my role is about administration" while another quantified it as "It is 99 per cent management 1 per cent technical to be honest."

The emphasis on the managerial aspects of the PI role was mentioned by all of the PIs in our study and as one PI noted: "It is a research organisation, we are the scientists who are supposed to be driving the organisation, we are not supposed to be driven by the administration." This administrative inhibiting factor creates tension between managing the project from a *research leadership* perspective – the basis of the award – and *research management* or project administration. The reason for this rise in adminstration and management is best captured

by a senior professor who stated: "While the funding agencies still want to have a record of achievement and the universities want you to bring in money, the dynamic has shifted for PIs with both sides now increasingly pushing in on the PI at the same time to manage the project properly. What I find is that more and more is being pushed back to the PI in terms of management." This dynamic means that PIs have to manage their academic credentials as well at the publicly funded project. As one PI described it as: "So I need to maintain the academic persona in parallel with the coordination role."

The second most significant inhibiting factor we found was the *lack dedicated professional development support for publicly funded PI role.* PIs in our study participated in "generic training and professional development" activities focused on writing competitive proposal bids, and project management. For the majority of PIs in our study development relating to research leadership and management involved "self learning" and learning through experience, rather than any tailored and formalised training support that they received from their institution or funding agency. As one professor stated: "Most of it is self learning as far I am concerned… I fumbled through and found my own way, it is down to being sociable and confident", while another professor commented "it really is 'in at the deep end' stuff". Another agreed with the self learning aspects of being a publicly funded PI: "if you compare what I know now to what I knew in 2002 it is primarily down to self-learning". Other interviews described the self-learning as "most effective" but also described it as learning "the hard way". However some PIs were skeptical about the value of the training they received particularly with respect to managerial training as one researcher reflected: "I have gone on a few management courses that were not very good or applicable."

The third significant inhibitor that publicly funded PIs experienced was the *power of industry partners*. The power that industry partner over publicly funded projects and PIs is not in doubt as a research leader noted: "The reality is that industrial partner dictates a lot when they are getting involved." The influence that industry has extends from the project conception right through to the project itself, which can be difficult for PIs to deal with. As one interviewee stated: "if you have an industrial partner that is involved in the direction of the project the research goals can change easily. Six months in they might say that they want something else and they might want you to change. You have to be pragmatic and see how that can be done whilst reminding them of the constraints." Securing industry partners can be difficult but maintaining their interest over the duration of the project can be "tricky".

The mismatch between industry and project timeline can be an inhibiting factor for some publicly funded PIs, where companies need more immediate outcomes such as a "product coming off the line in the next six months." As one researcher stated: "industrial partners don't understand the dynamics like 'can't hire' or 'PhD students are not delivering' or whatever it might be." Moreover, we found that industries real interest in publicly funded projects can change dramatically. One professor reflected this trend by noting: "My experience with industry partners would suggest that they don't tell you too much about what they are doing and how close you are to solving the problem. On one project I was working on the industry partner all of a sudden stopped their funding. There are two likely reasons for this, either they have given up on it or else they have solved it and they won't tell you as they will then bring it in-house. This puts huge pressure on you as a PI and it makes for a very volatile situation".

5. DISCUSSION

In this paper, our research focused is to examine the inhibiting factors that publicly funded PIs experience in leading publicly funded research projects. We identified three main categories of inhibiting factors: (1) *Political and Environmental*; (2) *Institutional*; (3) *Project Level* as well as identifying the associated tensions it created for publicly funded PIs.

At an institution level the findings highlight the inadequate nature of the research supports available in large publicly funded organizations that are dependent on state to fund core activities and whose research funding income is balanced towards public funding. It also highlights the influence of industry partners in publicly funded projects. Our findings in relation to inadequate research supports concurs with some of the findings of Alder et al (2009) on the managerial challenges encountered when managing research activities. In particular, the lack of leadership development opportunities for researchers and multiple (and sometimes contradictory) expectations and logics from different stakeholders. The lack of formal structured preparation to becoming a PI in what are normally large-scale collaborative projects in context where the existing support structures are 'stretched' with limited human capital support, means that PIs tend towards research management rather than research leadership. In addressing the question posed by Shelly (2010) the evidence from our study suggests that the balance for publicly funded PIs is that they spend a significant proportion of their time on administrating the research process and less on research leadership. The danger is that publicly funded PIs in the absence of dedicated support have embraced research management more than research leadership. In essence, they have learned 'management skills on the fly' as Kreeger ((1997)described it. It would appear that PIs have adopted a hybrid role that employs a scientific and managerial persona rather than a scientific and entrepreneurial persona

as Jain et al (2009) argues. This creates significant tensions for the PIs who have a significant interest in public research but little or no control over any of the inhibiting factors that we identified in our study.

5.1 Research Bureaucracy and Research Management Focus

Our findings raise some fundamental questions for the organisation of publicly funded science and the role of the PI. Whilst not reported in this paper, our research reaffirms many of the positive benefits of public research that have been identified in the literature (Cunningham et al, 2012). However, from a PI perspective, our findings also suggest that may not be the "freest form of support" as suggest by Hackett (1990), and that publicly funded PIs are inhibited to a significant extent in relation to the development of new knowledge, methodologies and scientific instruments as project level administrative and managerial activities have come to overshadow scientific activities. The transparency and accountability that is now required by publicly funding agencies, facilitated by HEIs and research laboratories has significantly increased the administrative burden on PIs, and this has not been alleviated or supported with sufficient institutional or funding body resources.

The leadership focus of the PIs in our study has focused more on research management and administration and less on research leadership. While institutions may "promote more risk taking, self confidence, optimisim and ambition" (Glassman et al, 2003), the coercive force of public funding that Hackett (1990) outlines undermines this institutional environment. Consequently, the publicly funded PIs do not have the research autonomy that is characterized by public research, nor have they adequate institutional support. More critically, the publicly funded PIs have no control and little influence in overcoming many of these inhibiting factors. Given their boundary spanning roles, publicly funded PIs bear exaggerated expectations by their own institutions, funding agencies and industry partners. The study also highlights the role ambiguity that places increased stress on the decision maker in our study, the publicly funded PI.

The expanded core mission withinuniversity and public research laboratory environment, coupled with resource dependency and role ambiguity has raised some significant new tensions and conflicts for publicly funded PIs beyond what Siegel et al, (2003) described for academics and has resulted in some unintended consequences (see Clark, 1987). The traditional craft skill of a publicly funded PIs of research leadership is shifting towards managing the mechanism of research (Shelly, 2010). To deal with some of the coercive forces and the bureaucracy of public research, publicly funded PIs need to develop new craft skills that combine research leadership and management, particularly as they receive insufficient support from funding agencies, their own institutions. The extent of this is worrying and has implications for value and impact that is generated from public research and the real utilization of research leadership skills of eminent researchers. Furthermore, self-learning is not the optimal manner for publicly funded PIs to acquire appropriate research management skills and behaviours.

5.2 Core Tensions

In examining the inhibiting factors our study identified some core tensions experienced by publicly funded PIs. Key tensions are focused on the desired 'entrepreneurial' versus scientific outcomes; generic versus dedicated supports for the PI role; IP protection versus IP exploitation; formal learning versus self-learning; and research management versus research leadership. These micro level tensions generated by inhibiting factors experienced by publicly funded PIs reflect clearly the changes that have occurred in academic life and the influence of 'commercial and managerial environments' (see Dany et al. 2011 and Duberley et al, 2006). In responding and dealing with these tensions, we found that publicly funded PIs have a high level of interest in all of these that directly impact on their role but have low levels of control over many of the inhibiting factors, despite the fact they are eminent researchers who are key core actors in delivering public research. As a key stakeholder in publicly funded science their power to influence and control is low. Moreover, the tensions that we have unearthed and the inhibiting factors run contrary to the cultural environment of a university-type organisation that Glassman et al, (2003) suggests that "promotes risk taking, self confidence, optimism and ambition."

5.3 Managerial approach

The managerial approach that has been adopted by many universities and public research laboratories as well as funding agencies, which has resulted in changes to academic work environments. The managerial approach of public funding agencies is evident in the project level inhibitors that we identified in our study. We would argue based on our study that this has shaped PIs to a greater extent that their own institutions (Clark, 2011). More significantly, the inhibiting factors potentially undermined PI loyalty to their institutions given the lack of tailored dedicated supports they received being a publicly funded PI. This is in contrast to the prestige and resources that they bring to the institution in securing public funding. Consequently, we argue that this potentially undermines the 'quality of professional life' of the publicly funded PI experience and can potentially decrease job satisfaction and performance contrary to what is argued in the literature(Shinn, 1988). The inhibitors that we have identified potentially could exacerbate this for individual publicly funded PIs, which could ultimately lead to scientists leaving national systems or organisations where inhibitors created by involvement in publicly funded are most prevalent and are insurmountable.

5.4 Undermining the Ethos of Science

The inhibitors that publicly funded PIs experience, that we identified, have created 'new fault' lines (Owen-Smith *et al.*, 2001), which encompass a wider set of stakeholders inside and outside universities and public research laboratories. Our findings support those of D'Este and Perkmann's (2010) study that publicly funded PIs primary motivation is research enhancement, but we argue that the inhibitors have the potential to undermine the traditional values and identity of scientists (Goketepe-Hulten and Mahagaonkar, 2010) and even de-motivate academics from engaging in public research programmes. The experienced realities of public funding and the inhibiting factors and the associated tensions have the potential to undermine what Merton (1968) termed the 'ethos of science'. Public funding in some respects provides scientists with the enabling capacity to prioritize discovery and provide research autonomy. Based on the evidence from our study it can undermine scientist's prioritization of discovery and places even greater managerial and administrative constraints on PIs that is not adequately supported. More fundamentally, we argue that the inhibiting factors and research managerial focus of PIs is a function of the mixed messages that their own institutions, funding agencies and national governments attach to the key activities of academics and publicly funded PIs. In essence, publicly funded PIs experiences are shaped by the controls and bureaucracies of their own institutions and funding agencies.

6. Conclusions

Our results have captured the significant inhibiting factors and the associated tensions for publicly funded PIs, but have implications for public funding of science, formation and professional development of PIs, universities and public funding agencies. There is no doubt that there is demand and a need to continue public funding of science, particularly when large investments have been made in building infrastructure, human capital and where there is sustainable industry involvement. However, the 'ethos of science' and the prioristisation of discovery must be protected and nurtured. An erosion of this core principal has the potential to undermine science as a profession and the reputation aspects of being a scientist that competes for securing public funding.

Our study also brings into focus how PIs are prepared for the role. Publicly funded PIs have experienced institutional support in pre-funding application phases, but do not receive sufficient dedicated or tailored support for the actual project. While PIs have experienced support from their institutional central services they are not sufficiently focused on their specific needs as publicly funded PI that has dual controls and bureaucracy from their own institution and the funding agency. They are not 'meaningful' as one PI put it. However, is a 'self-learning' or apprenticeship approach sufficient to becoming a PI? We would argue there is a need to readdress the research management and research leadership balance that PIs experience and, via institutions and disciplines, better prepare academics for the PI role, which continues to been seen as prestigious in the profession.

For publicly funded universities, the study raises the issues in relation to appropriate institutional support for publicly funded PIs post funding. So, how can universities support PIs on the one hand to carry out the necessary administrative duties that are required for public funding, particularly transparency and accountability, that do not over shadow their research leadership and scientific duties, the basis on which they secured public funding in the first instance. The more concerning issue for universities is if publicly funded PIs are taking on more managerial and research management activities and not devoting sufficient time to research leadership, then over time the danger is that their competitiveness in securing research grants lessens.

For funding agencies, there appears to be a need to engage with publicly funded PIs in a manner that is both challenging and supporting. More consideration in funding calls should be given to the leadership and managerial capabilities of applicants but also the types of dedicated PI supports institutions actually provide. In addition, there is a need for funding agencies to articulate consistently to their stakeholders clear and consistent statements as to their core activities and future intentions and well as ensuring operational efficiency in terms of the research programmes that they manage. In essence funding agencies need to consider the research management required to successfully compete funded research programmes that address transparency and accountability but that does not impede research autonomy. It also means that careful consideration needs to be given to the impacts that funders are attempting to achieve particularly technology transfer and the appropriate experience of the publicly funded PI and their institution in achieving such outcomes. Otherwise, publicly funded research and PIs may not receive articulated benefits such as private funding for technology transfer (Rubenstein, 2003), incremental GDP (Vincett, 2010), diversification of institutional funding (Geuna, 2003) or increased capacity for scientific and technological problems.

Finally our results suggest that the role of publicly funded PIsextends beyond scientific leadership to managerial leadership. The question of public good dominates the rationale for the re-positioning of the role of academic organisations in society, as the emergence of the third mission changes on a fundamental level the manner in which university research is expected to contribute to society. The evidence from our study would suggest that publicly funded PIs are the core of the fundamental shift within universities and public research laboratories which if not managed carefully has the potential to lead to unexpected consequences. There is no doubt that publicly funded PIs have experienced "the rules and formal rationality of government bureaucracies" as Hackett (1990) notes both from publicly funded research agencies and those in publicly supported universities and

research laboratories. The danger for public funding of science is the balance may be more towards accountability and transparency, which is a treshold requirement and less on priorisatisation of new knowledge which is at the heart of scientific discovery as Merton (1968).

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Table 1: Characteristics of Public Research

	Public research characteristics
Autonomy	Traditionally, public research is identified as the "freest form of support" (Chubin *et al.*, 1990).
Ownership	Publicly funded research is owned and financed by government. Scientific knowledge produced from public research is identified as a public good(Callon, 1995; Stephan, 2004).
Type of research	Includes significant levels of applied research and most basic research which tends to be excluded from R&D activities administered under market conditions (Drejer *et al.*, 2004).
Public funding allocation models	Varies across national innovation systems and dependent on national priorities (Mangematin, 2004). Alternative and evolving funding allocation systems including allocation through public competition and incentive structure allocation systems (e.g. key performance indicators such as bibliometric performance) (Link *et al.*, 2012).
Governance	Public pressure for ensuring informed spending of public money(Lyall *et al.*, 2004). Consequently, public funding increases the levels of accountability and transparency required (Hackett, 1990).
Location	Typically located at universities and public research laboratories with resultant influences of organisational strategies, processes, systems and cultures.
Performance evaluation	Influenced by research organisation and includes scientific output and impact, economic impact, scientific and technical human capital impact, and political impact (Bozeman, 2000). Social benefits (Rubenstein *et al.*, 2003)

Table 2: Benefits of Publicly Funded Research

Public	Incremental GDP benefits from patent licensing and new spin-offs (Vincett, 2010). Supply of skilled graduates (Mangematin *et al.*, 2003). Increased capacity for scientific and technological problem solving (Puay Tang *et al.*, 2007). Supports the adoption of socially desirable research which otherwise may not receive private funding (Rubenstein, 2003).
Research Institution	Development of new knowledge, methodologies and scientific instruments (Joly *et al.*, 1996) Strengthening of relationships with research stakeholders, including industry (Bozeman *et al.*, 2007). Diversification of institutional funding (Geuna *et al.*, 2006) or equipment (Nedeva *et al.*, 1999).
Individual Scientist	Expansion of networks for knowledge production and social interaction (Callon, 1995). Increased personal income through royalty payments from patents or spin-outs (Göktepe-Hultenet *et al.*, 2010)

Table 4: Significant Inhibiting Factors and Tensions Experienced by Publicly Funded Principal Investigators

Inhibiting Factor	Tension
Technology Transfer Direction and Focus Competing Stakeholder Interests IP Valuation	'Entrepreneurial' activities versus scientific outputs.
Poor Support Reliability of Public Funding Agencies	Balancing existing workloads versus applying for new funding opportunities.
Engagement Variation and Interest Publicly Funded Research Agencies	Formal paper based contact versus active support and scientific interrogation and analysis.
Technology Transfer Support	IP protection versus IP exploitation.
Dedicated Support for the PI	Generic skills versus tailored leadership support.
Human Capital Support	Project sustainability versus continual loss of talents and experiences.
Administration	Research management versus research leadership (driven versus driving).
Training and Support	Formal learning versus self learning.
Power of Industry Partners	Timeline and project objectives mismatch.

Table 3 PI Interviews Overviews

Principal Investigator Details				Project Details		
Gender	Title	Institution	Area of Research	Focus	Partners	Nature
Male	Research and Training Coordinator, Dr.	University	Marine Science	National	6	Applied
Female	Research Development Officer, MBA	Public Research Laboratory	Marine Science	National	9	Applied
Male	Research Leaders, Dr.	Public Research Laboratory	Food Science	National	2	Basic
Male	Research Leader, Dr.	Public Research Laboratory	Food Science	National	3	Basic
Female	Head of Food Safety Research, Dr	Public Research Laboratory	Food Science	National	6	Basic
Female	Research Leader, Dr.	Public Research Laboratory	Food Science	International	9	Basic
Male	Professor	University	Food Science	International	12	Basic
Male	Research Unit Leader, Dr.	University	Web Science and Technology	National	2	Applied
Male	Professor	University	Computer Science	International	2	Applied
Male	Research leader, Dr.	University	ICT	International	10	Applied
Male	Research Unit Leader, Dr.	Institute of Technology	ICT	International	10	Applied
Male	Executive Director	Institute of Technology	ICT	National	2	Applied
Male	Executive Research Director, Dr.	Institute of Technology	ICT	International	5	Applied
Male	Professor	Institute of Technology	ICT	National	2	Applied
Male	Deputy Research Director, Prof.	University	Physics	International	3	Applied
Female	Senior Researcher, Dr	University	Physics	National	3	Applied
Male	Senior Researcher, Dr.	University	Physics	National	2	Basic
Male	Professor	University	Physics	National	2	Basic
Male	Professor	University	Physics	National	2	Basic
Male	Research Centre Director, Prof	University	Chemistry	International	11	Basic
Male	Research Leader, Dr.	University	Chemistry	International	7	Applied
Male	Lecturer, Dr.	University	Chemistry	National	2	Applied
Male	Professor	University	Geological Sciences	International	9	Basic
Male	Professor	University	Biotechnology	International	3	Basic

Female	Professor	University	Biotechnology	International	4	Applied
Male	Lecturer, Executive Research Director, Dr.	University	Engineering	National	2	Applied
Male	Professor	Institute of Technology	Engineering	National	3	Applied
Female	Senior Researcher, Dr.	University	Engineering	International	5	Applied
Male	Executive Research Director, Dr.	University	Engineering	International	2	Basic
Male	Research Unit Leader, Dr.	Institute of Technology	Engineering	National	2	Applied